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THE NATURE OF COAL HORIZONS.

THE Coal Measures of the Mississippi valley occupy an area of more than 120,000 square miles. They extend in an almost unbroken field from the western flank of the Appalachians on the east to beyond the Missouri river on the west. Separating the area into two somewhat unequal parts is the Mississippi river along the course of which are exposed older rocks. The Coal Measures may have been at one time continuous over the central portion, but the outcrops of the more ancient rocks along the borders of the Mississippi is probably not due entirely to unaided erosion but in part to slight folding, an anticlinal axis coinciding approximately with the line of the great river.

The geological history of the eastern and western areas, which are sometimes called respectively the Central and the Western Interior coal fields, is probably similar, though in some particular phases there is a divergence which dates back prior to the close of the Lower Carboniferous. The northern portion of the Coal Measures west of the Mississippi forms a broad bay-like expansion opening to the westward. Beyond the Missouri river the strata are hidden from view by newer sediments. The most productive portion of the Western Interior coal field is a marginal zone extending from northcentral Iowa southeastward to northeastern Missouri, thence sweeping to the westward around the Ozark uplift into Indian Territory and continuing on into central Texas. The interior portion of the bay-like expansion of Coal Measures is as a general thing unproductive, though a few thin seams of coal do occur.

Everywhere throughout the region the stratigraphical details present great simplicity, being almost free from the effects of orographic movements. The lithological characters of any one locality are repeated again and again in the same monotonous succession. The faunal and floral features are practically identical from one end of the great coal basin to the other.

The greatest interest, economically and geologically, in the Carboniferous basin centers around the coal deposits. Their disposition perhaps comes first in importance, both from the standpoint of the operator and of the geologist. The subject is certainly one of wide-reaching import.

There is now abundant evidence to show that the Western Interior coal field at the time of deposition was for the most part a broad, shallow basin opening to the westward into the great continental sea which then occupied most of what is now known as western North America. That the Coal Measures of the region were laid down during a period of gradual, prolonged, though often checked, subsidence is evidenced by all stratigraphical and lithological details, as well as by the characteristic faunal peculiarities. That the coal beds originated largely in coastal swamps of limited breadth but, with some interruptions, of very considerable length, stretching out near sea level for long distances and sending out minor extensions into the old rivers and estuaries is fully warranted by the facts disclosed everywhere. On the low, slowly sinking shores there prevailed at certain times a similarity of physical conditions especially favorable to coal formation. During these intervals unusual amounts of coaly material were allowed to accumulate and to be preserved in places, the period being preëminently one of coal growth, at least for a given province. The great stratigraphic plane marking each record may be appropriately termed a "Coal Horizon."

In stratigraphy, a geological horizon is a level recognizable over a considerable geographical extent, having a more or less well defined stratigraphical position, distinctive as to lithological features and characterized by a particular set of fossils. The term in a broad sense is almost equivalent to formation, and has been used as indefinitely. In its more limited meaning it is applied properly to a minor part or zone of the smallest stratigraphical unit having a commonly accepted specific name. Understood in the same way, a "Coal Horizon" represents an even more limited expansion, where coal forming materials have accumulated. Practically it is one of the greater planes of sedimentation, marking a distinct episode in the deposition of a series of strata. Theoretically it represents not a phenomenon, but rather a set of conditions, a period during which the physical circumstances were similar over a considerable marginal portion of a geological province. From an economic standpoint it stands not for a continuous bed of mineral fuel, but a stratigraphical level where workable beds are more likely to occur than elsewhere, and where the coal is to be especially sought for in a wide belt fringing a great coal basin. It is not to be inferred, then, that the mineral is equally developed on a given horizon in all portions of this marginal border. In some places the accumulations of plant remains are much greater than in others; limited basins and troughs of unusual thicknesses are there found. Elsewhere the old vegetable materials are meagerly represented; only thin seams of coaly matter are there preserved. Wide intervals of sandstone and shale often separate adjoining basins, or ancient land elevations may cut off one area from another. (Figure 1). Yet, through all of the many irregularities of deposition and subsequent deformation there are nevertheless discernible, certain levels quite well defined at which coal beds are very much better developed than at others; clearly marked coal horizons they are, broad in extent and capable, in the case of the greater ones under favorable circumstances, of being traced over a large part of a given Coal Measure province. The coal may not be present in a continuous seam over the whole border district and probably never is; but along much of the

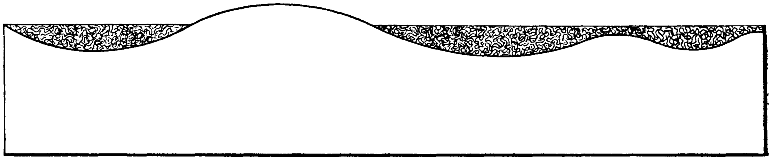

FIG. 1. Coal Horizon at time of formation; parallel to shore line.

margin of the coal horizon, which at one time must have stood near the sea level for a considerable period, are innumerable basins separated from one another perhaps, yet to all appearances formed contemporaneously. Now they may thicken into sharply defined lenticular beds; now thin out to mere films, or disappear altogether; and again further on they assume the form of extensive lens-shaped sheets. During deposition, as subsidence became too rapid or the sea too deep for the proper accumulations of vegetable material, sediments were carried in covering the plant beds. Or, if elevation took place the old swamps, already shut off from free access to the sea, were subject to the agencies of denudation and were partially or entirely removed. As favorable physical conditions again set in the same course of events might be repeated.

In considering the relations of the different coal horizons to one another an approximate parallelism may be made out. Not a strict parallelism of the nature which Andrews[1] claimed to be true in Ohio, and which Newberry[2] subsequently stated to be entirely unsubstantiated by facts, but an approximate parallelism in a broad way.

There was apparently a germ of truth in the idea of the first named author, though he was probably unfortunate in the choice of a name for his theory. Moreover, none of his writings indicate that he understood the problem in the way that recent investigations reveal it. His statements all seem to show that, while he was manifestly on the right path, only one side of the subject had been presented to him, just as, quite recently, the question has been discussed from the opposite extreme. Andrews' views are perhaps best expressed in the following paragraph taken from his paper[3] on the subject:

"I have never found the slightest proof of the formation of a seam of coal over hills or high grounds. The parallelism of the seams, of which further mention will be made, forbids it.

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[1] Geol. Sur. Ohio, Vol. I, p. 348. Columbus, 1873.

[2] Geol. Sur. Ohio, Vol. I, p. 169. Columbus, 1874.

[3] Geol. Sur. Ohio, Vol. I, pp. 348–350. Columbus, 1873.

. . . . So far as my observations go, I have never found an instance where two distinct seams of coal came together or, conversely, where a seam became divided and its parts continued to diverge for a long or indefinite distance. It is not uncommon to find, in a seam of coal, the proof that the coal marsh had in it local depressions, which were filled with sediments, making a soil on which new vegetation grew, and thus the seam shows two parts, separated by fire clay sometimes several feet thick; but in every instance when traced I have found the parts to reunite. The two parts never diverge indefinitely. From these statements we may infer a general law of parallelism. Such law is in harmony with the belief of the most careful observers, that our productive Coal Period was characterized by great quietness and freedom from violent local disturbances."

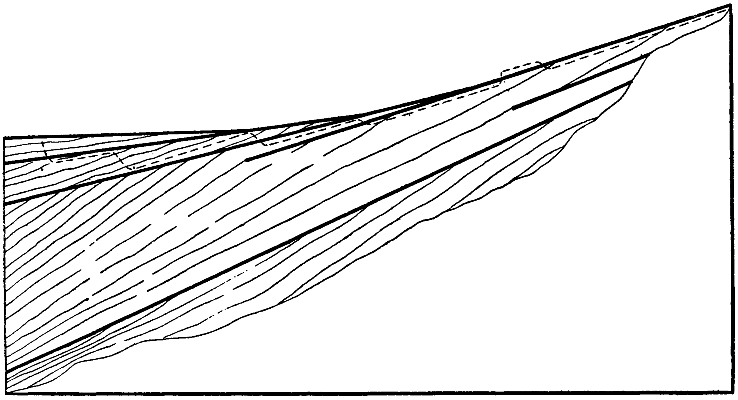

FIG. 2. Stratigraphy of Coal Beds.

This describes the apparent condition of things in Ohio. The same with minor modifications and explanations may be regarded as according fairly well with the facts observed in the Iowa-Missouri coal field.

On the other hand there are many who, with Newberry, have directly opposed any approach to the recognition of the parallelism of coal veins. Among the latest opinions on this side of the discussion is one expressed by Winslow,[1] who in considering the stratigraphy of Missouri coal seams is led to believe that the different veins diverge from one another in a manner best explained by the preceding diagram, the dotted line representing post-Carboniferous erosion. (Figure 2).

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[1] Geol. Sur. Missouri, Rep. Coal, pp. 28–30. Jefferson City, 1891.

These conditions also accord in the main with the facts observed in all the Western coal fields.

An attempt to harmonize the two seemingly very divergent and even contradictory theories is apparently fruitless. But a more careful examination of the subject shows that the two theories are manifestly not based on facts taken from the same point of view, but from quite different positions. Andrews' idea may be taken as representing a cross section of the coal bearing strata taken parallel to the general course of the shore ; Winslow's a section at right angles.

In districts where mountains are being elevated, orographic movements in the earth's crust continue to be felt for long distances from the line of maximum disturbances. If a great sea or an ocean occupies a region affected to a moderate extent by the oscillations, an extended shore line trends approximately with the axis of the mountain system, for the more important minor corrugations commonly run in similar parallel lines. The direction of maximum change in the inclination of strata is therefore at right angles to the axes of the folds, and hence in a broad way perpendicular to the shore line. The direction of minimum change in tilting is, under ordinary conditions, the same as the axes, or parallel to the shore. Bearing these suggestions in mind geological cross sections, under favorable circumstances of examination, would show a general parallelism of coal beds when made in one way; a decided tendency to non-parallelism when constructed in the other.

Granting, then, an old, uneven land surface, such as is known to have existed in Carboniferous times in the upper Mississippi basin, with the waters of the sea and the marginal maritime flats gradually creeping inland, it would naturally be expected that in the case of any one of the marshy plains skirting the shores for any great distance there would be a very tortuous boundary on the land side and a somewhat less sinuous line on the seaward side ; on the one hand were probably low hills and uplands sending out spurs here and there which cut off one marsh from another and often allowing long open stretches of low upland to reach out even to the waters of the sea itself; on the other hand were often narrow coastal plains rising scarcely above sea level, but, to a great extent, shutting off very effectually the saline waters from the swamps. Viewed areally, the productive portion of one of the great coal horizons is a wide irregular zone running in a tortuous course around a more or less extensive portion of the margin of a coal bearing basin included within the limits of a geological province. Examined at the present time coal horizons present, with all the irregularities of original deposition, subsequent change and deformation, a quite different aspect from the ideally perfect level of the ancient surface or zone which existed during the period of formation. In one direction, parallel to the shore, there is a series of minor saucer-shaped basins strung along on about the same great stratigraphical plane. They may rise or fall as the other strata change in inclination. They may be separated by wide stretches of sandstone or shale, or may come together in places. In the different basins the original vegetable materials in becoming compact shrink most in bulk in the middle, thus allowing the margins to remain considerably higher than the center. This is more noticeable in small basins than in large ones. Then, too, the fact that the direction of minimum movement in the changes of level was, as has been shown, parallel to the prevailing trend of the shore does not preclude even in this direction a certain amount of tilting of the strata either by the rising or the sinking of one portion of the shore more rapidly than another; or by the passage of some of the minor folds in directions not strictly harmonious with the general movement.

When a new cycle of vegetable accumulation took place the coastal swamps would again spread out at sea level, but not necessarily on planes exactly parallel to the horizon previously formed. Horizons which were separated to very considerable distances by shales or other strata, probably are rarely exactly parallel to one another, or if so, the parallelism is purely coincidental. There are many causes which in places lead to the non-parallelism of the coal horizons. The original bottom of the sea may have been very uneven, as is well shown in the very irregular surface of the Saint Louis limestone on which the Coal Measures were laid down. Or, in two different seams the inequalities may be great, the extremes often occurring in the same locality, and thus presenting a much greater apparent unevenness than really exists. Erosion or currents may have altered the position of the seams or parts of them. The top of the seams which were originally level became subsequently depressed in the center more than at the margins. There are also other causes tending to widen the seeming discrepancies. (Figure 3).

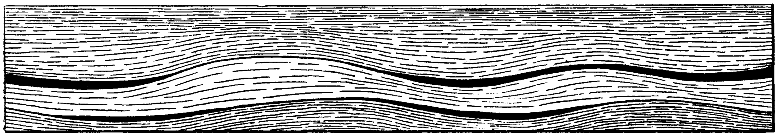

FIG. 3. Coal Horizon as it now exists; parallel to shore line.

In another direction, at right angles to the old shore, the minor basins along the different horizons may appear to show no tendency to parallelism at all. The approach to the parallel condition is inversely proportional to the amount of deformation occurring in the region at the time of the formation of the coal beds. Instead also of the seam being continuous for a considerable distance across the coal basins, as may be inferred from Winslow's graphic representation, the productive coal strata should be confined to a limited marginal area and the coal horizon would only extend into the interior as a great stratigraphical plane, not easily recognizable perhaps, nor with any of the mineral itself to mark it. (Figure 4).

The conditions described apply particularly to the coal fields of Iowa and Missouri, where comparatively few disturbances of the strata have taken place. The relations are relatively simple. But in Ohio and Pennsylvania, as the mountains are approached, the structure increases rapidly in complexity, until in the highly folded and faulted districts attempts to follow out the original state of things may become utterly hopeless.

The majority of the larger coal deposits of the Western Interior field may be considered then as having been formed in swamps skirting a great shallow gulf, the extent of the productive portions of the different horizons being in a measure dependent upon the length of time the physical conditions were favorable to coal formation. Many short minor episodes doubtless existed between the larger ones, during which comparatively small accumulations of vegetable material took place.

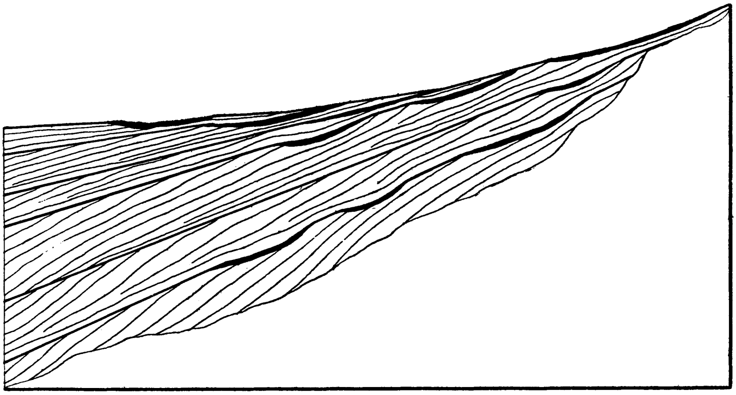

FIG. 4. Coal Horizon viewed at right angles to shore line.

Another fact to be taken into consideration is that all the coal of the region was not formed in marine swamps, but that some of the minor basins were doubtless originally a very considerable distance from the sea, while certain others were formed where open sea conditions prevailed largely. A few seams also appear to have been formed as drift materials in estuaries at the mouths of streams.

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